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 The Duration of this contract was spent performing a literature search on current techniques for analysis and synthesis of conformal scanning antennas mounted on a cylinder. The main contribution is a reference list and the recommendation for combining asymptotic mutual coupling with gtd fuselage modeling for antenna pattern calculations. The important technique of beam shape modification at low scan angles through the use of modified surface impedance structures is also mentioned.

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FINAL SUMMARY REPORT
AFOSR MINI GRANT #78-3624

LOW SCAN ANGLE PERFORMANCE
OF AIRBORNE FLUSH MOUNTED
COMMUNICATION ANTENNAS

BY

DR. V. P. CABLE
CALIFORNIA STATE UNIVERSITY, NORTHRIDGE
JANUARY 1980



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INTRODUCTION

World-wide communication links between aircraft and satellites place specific requirements on airborne antenna performance [1]. These requirements include antenna gains ≈ 30 dB and hemispherical scan coverage. The antennas used in present aircraft/satellite communication links are most often of the mechanically steerable reflector type and placement of the antenna has not been at issue since the antenna itself is located outside the main fuselage and must be covered by a rather large radome. The gain and scanning coverage of this overall antenna/fuselage system do not appear to have been studied either on an experimental or a theoretical basis. This does not seem unreasonable however, since gain and scanning range should not vary significantly from free space performance for these "raised" (or protruding) antenna systems.

Supersonic aircraft will no doubt be required to also participate in these satellite links in the near future and the primary impact of this will be on the antenna itself. Here, flush mounted electronically steerable arrays will be needed to satisfy the aerodynamic requirements of the fuselage. These flush arrays however, will generally be limited in practical gain and scan coverage [2]. Antenna performance in this case will be greatly affected by the fuselage structure.

Experimental studies of size and placement of these conformal arrays for optimum hemispherical coverage do not seem practical for either full sized aircraft or smaller scaled models. Hence, a theoretical model for simulating practical array configurations would be a valuable tool.

Significant theoretical work in airborne antenna pattern analysis has been made by Burnside, Marhefka and Hu [3,4,5]. The models used by Burnside, et. al. are based on high frequency GTD (Geometrical Theory of Diffraction) techniques developed by Kouyoumjian and Pathak [6,7]. Their analysis was confined to pattern calculations for verification of adequate coverage for specific antennas placed on the fuselage and wings. Other work based on these same GTD techniques has been done by Balanis, et. al. [8] for the MLS (Microwave Landing System) where simple slot antenna patterns were calculated in order to study coverage and polarization in the forward elevation plane.

DESCRIPTION OF WORK ACCOMPLISHED UNDER
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The major effort of this study was to perform a literature search on electronically scanned conformal phased array antennas. The work of Borgiotti [9,10] and Borgiotti and Balzano [11,12] on periodic array structures and also the work of Shapira, Felsen and Hessel [13,14], Sureau and Hessel [15] and Knittel, Hessel and Oliner [16] on ray analysis and element patterns in periodic arrays were first studied in detail. Much of this work, of course, applies only to infinite or semi-infinite periodic arrays, planar or otherwise.

An investigation of the work done on finite array structures shows Steyskal [17] work to be one of the only theoretical studies done in this area (circular apertures on cylinders) while Mailloux, et. al. [2,18,19] and Kummer et. al. [20,21] have done much of the experimental work on finite "limited scan" arrays. The results of these finite array studies are valuable to this work in the sense of being the best available theoretical and experimental stepping stones to other possible conformal array structures (presently in existence or innovative developments in the future).

A study of mutual coupling between array elements and its effect on element gains and active reflection coefficients was also performed by reviewing the works of Edelberg and Oliner [22] and Wasylkiwskyj and Kahn [23]. The latest techniques for computing mutual coupling between apertures on cylinders and cones appears to be that of Lee, et. al. [24,25,26,27,28] while some of the most original theoretical work on impedance conditions over cylindrical structures (which incidentally, might prove to be last word in beam control for low scan angles) was done by Pathak [29] and Pathak and Kouyoumjian [30]. These overall asymptotic and GTD techniques from the Ohio State University and the University of Illinois are crucial to performing practical calculations on mutual effects over large cylindrical structures. The same can also be said concerning the ray optic and GTD techniques for computing field patterns associated with the entire antenna/fuselage structure.

In conclusion, it suffices to say that the time allowed for this study was basically just enough to gain a basic understanding of the latest techniques for investigating conformal phased array structures. A simple 3-D array scan model was developed however, using a hybrid of the techniques described by Stewart and Golden [31], Lee, et. al. [24] and Burnside [2] and a portion of a Master's Degree Project [32] was derived from this study. Hence, these results have been of significant educational value to this University and to its graduate program in antenna engineering.

REFERENCES

- [1] J. P. Grabowski and F. L. Lanphear, "SHF High Power Airborne Communications Antenna," presented at USAF Rand Antenna Symposium, University of Illinois, October, 1970.
- [2] W. G. Mavroides and R. J. Mailloux, "An Array Technique for Zenith to Horizon Coverage," RADC in-house technical report number 76-360, November, 1976.
- [3] W. D. Burnside, "Analysis of On-Aircraft Antenna Patterns," The Ohio State University ElectroScience Laboratory, Technical Report number 3390-1, August, 1972.
- [4] C. L. Yu and W. D. Burnside, "Volumetric Pattern Analysis of Fuselage Mounted Airborne Antennas," The Ohio State University ElectroScience Laboratory, Technical Report number 2902-2, April, 1976.
- [5] R. J. Marhefka, "Analysis of Aircraft Wing-Mounted Antenna Patterns," The Ohio State University ElectroScience Laboratory, Technical Report number 2902-25, June, 1976.
- [6] P. H. Pathak and R. G. Kouyoumjian, "Analysis of the Radiation from Apertures in Curved Surfaces by the Geometric Theory of Diffraction," IEEE Proceedings, Volume 62, No. 11, November, 1974.
- [7] R. G. Kouyoumjian and P. H. Pathak, "A Uniform Geometrical Theory of Diffraction for an Edge in a Perfectly Conducting Surface," IEEE Proceedings, Volume 62, No. 11, November, 1974.
- [8] C. A. Balanis and Y. B. Cheng, "Antenna Radiation Modeling for Microwave Landing System," IEEE Transactions AP-S, Volume 24, No. 4, July, 1976.
- [9] G. V. Borgiotti, "Model Analysis of Periodic Planar Phased Arrays of Apertures," IEEE Proceedings, Volume 56, No. 11, November, 1968.
- [10] _____, "A Novel Expression for the Mutual Admittance of Planar Radiating Elements," IEEE Transactions AP, Volume 16, May, 1968.
- [11] G. V. Borgiotti and Q. Balzano, "Analysis and Element Pattern Design of Periodic Arrays of Circular Apertures on Conducting Cylinders," IEEE Transactions AP, Volume 20, No. 5, September, 1972.
- [12] _____, "Mutual Coupling Analysis of a Conformal Array of Elements on a Cylindrical Surface," IEEE Transactions AP, Volume 18, No. 1, January, 1970.

REFERENCES (CONT'D)

- [13] J. Shapira, L. B. Felsen and A. Hessel, "Surface Ray Analysis of Mutually Coupled Arrays on Variable Curvature Cylindrical Surfaces," IEEE Proceedings Volume 62, No. 11, November, 1974.
- [14] ———, "Ray Analysis of Conformal Antenna Arrays," IEEE Transactions AP, Volume 22, No. 1, January, 1974.
- [15] J. C. Sureau and A. Hessel, "Element Pattern for Circular Arrays of Axial Slits on Large Conducting Cylinders," IEEE Transactions AP, November, 1969.
- [16] G. H. Knittel, A. Hessel and A. A. Oliner, "Element Pattern Nulls in Phased Arrays and Their Relation to Guided Waves," IEEE Proceedings, Volume 56, No. 11, November, 1968.
- [17] H. Steyskal, "Analysis of Circular Waveguide Arrays on Cylinders," IEEE Transactions AP, Volume 25, No. 5, September, 1977.
- [18] R. J. Mailloux and G. R. Forbes, "An Array Technique with Grating-Lobe Suppression for Limited-Scan Applications," IEEE Transactions AP, Volume 21, No. 5, September, 1973.
- [19] R. J. Mailloux, L. Zahn, A. Martinez III and G. R. Forbes, "Grating Lobe Control in Limited Scan Arrays," IEEE Transactions AP, Volume 27, No. 1, January 1979.
- [20] W. H. Kummer, A. T. Villeneuve and M. C. Behnke, "Hemispherically Scanned Arrays," Hughes Aircraft Company, Scientific Report No. 2, HAC Reference No. 2265.31/220, December, 1973.
- [21] W. H. Kummer, A. T. Villeneuve and P. C. Bargeliotas, "Pattern Synthesis of Conformal Arrays," Hughes Aircraft Company, Final Report, HAC Reference No. D0741 2265.30/470, January, 1974 - January, 1975.
- [22] S. Edelberg and A. A. Oliner, "Mutual Coupling Effects in Large Antenna Arrays: Part I -- Slot Arrays," IRE TRANS. P-GAP, May, 1960.
- [23] W. Wasylkiwskyj and W. K. Kahn, "Mutual Coupling and Element Efficiency for Infinite Linear Arrays," IEEE Proceedings, Volume 56, No. 11, November, 1968.
- [24] S. W. Lee, E. Yung and R. Mittra, "GTD Solution of Slot Admittance on a Cone or Cylinder," IEE Proceedings 1979, (Personal Communication).
- [25] S. W. Lee and R. Mittra, "Mutual Admittance Between Slots on a Cylinder or Cone," ElectroMagnetics Laboratory, Report No. 77-24, University of Illinois, December, 1977.

REFERENCES (CONT'D)

- [26] S. W. Lee, S. Safavi-Naini and R. Mittra, "Mutual Admittance Between Slots on a Cylinder," ElectroMagnetics Laboratory, Report No. 77-8, University of Illinois, March, 1977.
- [27] S. W. Lee and S. Safavi-Naini, "Simple Approximate Formula for Mutual Admittance Between Slots on a Cylinder," ElectroMagnetic Laboratory, Report No. 77-13, University of Illinois, July, 1977.
- [28] _____, "Approximate Asymptotic Solution of Surface Field Due to a Magnetic Dipole on a Cylinder," IEEE Transactions AP, Volume 26, No. 4 July, 1978.
- [29] P. H. Pathak, "A GTD Analysis of the Radiation from Slots in Planar and Cylindrical Perfectly-Conducting Structures with a Surface Impedance Patch," RADC Final Report No. TR 77-165, RADC, February, 1977.
- [30] P. H. Pathak and R. G. Kouyoumjian, "TM Surface Wave Diffraction by a Truncated Dielectric Slab Recessed in a Perfectly Conducting Surface," ElectroScience Laboratory Technical Report No. 3001-4, The Ohio State University, June, 1973.
- [31] G. E. Steward and K. E. Golden "Mutual Admittance for Axial Rectangular Slots in a Large Conducting Cylinder," Transactions AP, January, 1971.
- [32] Y. Klein, "Active Reflection Coefficient and Pattern of a Rectangular Array of Rectangular Waveguides on a Cylinder," Unpublished Master's Project, California State University, Northridge, June, 1980.